BASEM REPORTS

EDITED BY **PROFESSOR YANNIS P PITSILADIS** AND **DR NICK WEBBORN** - UNIVERSITY OF BRIGHTON

HOW SPORT AND EXERCISE MEDICINE CAN EMERGE STRONGER FROM A GLOBAL CRISIS

Professor Yannis P Pitsiladis BSc., MMEDSci., PhD, FACSM

Professor Yannis Pitsiladis has an established history of research into the importance of lifestyle and genetics for human health and performance. Following 15 years at the University of Glasgow, Scotland where he created the largest known DNA biobank from world-class athletes, he was appointed (in 2013) Professor of Sport and Exercise Science at the University of Brighton. Current research priority is the application of "omics" (i.e. genomics, transcriptomics, metabolomics and proteomics) to the detection of drugs in sport with particular reference to recombinant human erythropoietin (rHuEpo), blood doping and testosterone.

His most recent research is funded by the World Anti-Doping Agency (WADA) and by the International Olympic Committee (IOC), he is currently a member of the IOC Medical and Scientific Commission, a member of the Executive Committee and Chair of the Scientific Commission of the International Sports Medicine Federation (FIMS), a member of the Scientific and Education Commission of the European Federation of Sports Medicine Associations (EFSMA), a member of WADA's Health Medical Research Committee (HMRC), past member of WADA's List Expert Group and is a Fellow of the American College of Sports Medicine (ACSM).

He has published over 185 peer-reviewed papers, written and edited a number of books and has featured in numerous research documentaries (e.g. ESPN, BBC, NHK Japan, CNBC) and popular books (e.g. Bounce, The Sports Gene).

Dr Nick Webborn OBE MB BS FFSEM FACSM FISM MSc Dip Sports Med
Clinical Professor (Sport & Exercise Medicine)
Centre for Sport and Exercise Science and Medicine (SESAME)
University of Brighton

Dr Nick Webborn is currently Clinical Professor at the Centre for Sport and Exercise Science and Medicine, University of Brighton and Chair of the British Paralympic Association. Nick is one of the UK's leading sports medicine specialists with over 28 years' experience in the field.

He is a world leading expert in the area of Paralympic sports medicine and has attended 11 Paralympic Games, summer and winter. He was chief medical officer for ParalympicsGB at London 2012 and for the Invictus Games in 2014.

He is currently interim chair of the IPC Medical Committee and has been a member of the UKAD TUE committee (formerly through UK Sport) since 2004.

University of Brighton

MEDICAL PROVISION AT THE BRIGHTON MARATHON

ARTICLE BY **JONATHAN SHURLOCK**, **RACHAEL GRIMALDI** AND **ROB GALLOWAY**

The inaugural year of the Brighton Marathon was 2010, since then the event has grown into the 2nd largest marathon in the United Kingdom and the 12th largest in Europe.

Despite its size the event is only served by 1 hospital, the Royal Sussex County Hospital (RSCH), in contrast to the London Marathon which is covered by 15 hospitals. This limited secondary care cover necessitates a robust pre-hospital set-up to ensure rapid and effective healthcare provision to not only event participants, but also any individual who becomes unwell within the event "footprint".

Above: Figure 1 Extracorporeal Membrane Oxygenation (ECMO) demonstration performed by the Advanced Cardiac Arrest Team (ACAT). Photo: Jane Stokes (DJ Stotty Images)

SET-UP

The marathon medical team works in conjunction with St John Ambulance, South East Coast Ambulance Service and Brighton and Sussex University Hospitals NHS Trust to provide multidisciplinary emergency healthcare. They also work in partnership with Philips to ensure provision of pre-hospital diagnostic testing, state of the art monitoring and other essential medical equipment. This collaboration ensures safe and effective medical care can be delivered on the frontline in a unique pre-hospital environment.

The Brighton Marathon Medical Team comprises over 500 healthcare and allied healthcare professionals and first aiders, all volunteering their services and expertise to deliver an extremely high standard of care at the roadside, integrating a multitude of clinical services, whilst minimising impact on the local hospital.

Expertise includes volunteers from the fields of physiotherapy, podiatry, nursing, anaesthetics, critical care, emergency medicine, general practice, operating department practitioners, pharmacists, laboratory technicians and more. The marathon has an integrated roadside ECMO (Extracorporeal Membrane Oxygenation) team (*Figure 1*) as part of its Advanced Cardiac Arrest Team – the first of its kind in the UK. This cutting-edge inclusion of life-saving treatment is a hugely exciting addition to the medical team.

RAPID SUPPORT

On Race Day, the Marathon control room situated at the Grounded Events Company HQ manages the event. Embedded within this team is the medical control room. The medical director, Dr Rob Galloway, provides mobile oversight and support across the whole event footprint via bicycle. This mobility enables rapid support at any critical incident and ensures effective coordination of care provision.

The medical director is supported by 3 Deputy Medical Directors – Rachael Grimaldi, Rob Greenhalgh and David Bowen. Medical logistics is lead by Carrie Weller in partnership with the St John Ambulance team led by Darren Owen, Hannah Pool and Trevor Moss. There are two main medical tents, an advanced first aid tent and 13 other smaller first aid tents. There are walking teams based at each first aid post as well as cycle response teams, each carrying defibrillators.

The two primary medical tents contain a broad range of healthcare professionals including St John Ambulance volunteers, podiatrists, physiotherapists, nurses and doctors. The tents are arranged similarly to a standard emergency department (*Figure 2*) with separate areas for triage, physiotherapy, podiatry, minors, majors and resus. These areas are equipped to manage a broad range of medical presentations from soft tissue injuries to cardiac arrest.

Over the marathon weekend, the medical team is responsible for all individuals within the marathon event footprint.

Therefore the tents are equipped to provide lifesaving care that would otherwise be delayed while awaiting transfer to hospital. Each medical tent is led by experienced senior healthcare workers, thus allowing a safe learning environment for trainee volunteers working outside of their usual roles.

These two areas manage the majority of clinical presentations, and in 2019 assessed and treated 350 individuals, including 50 collapsed runners, 7 of whom required onward transfer to Brighton and Sussex University Hospitals NHS Trust Emergency Department.

Above: Figure 2 Layout of the finish line medical tent. Photo: Jane Stokes (DJ Stotty Images)

> **"In 2016 the concept of an Advanced Cardiac Arrest Team (ACAT) was introduced, led by a highly experienced pre-hospital consultant."**

ADVANCED MOBILE MEDICAL UNIT

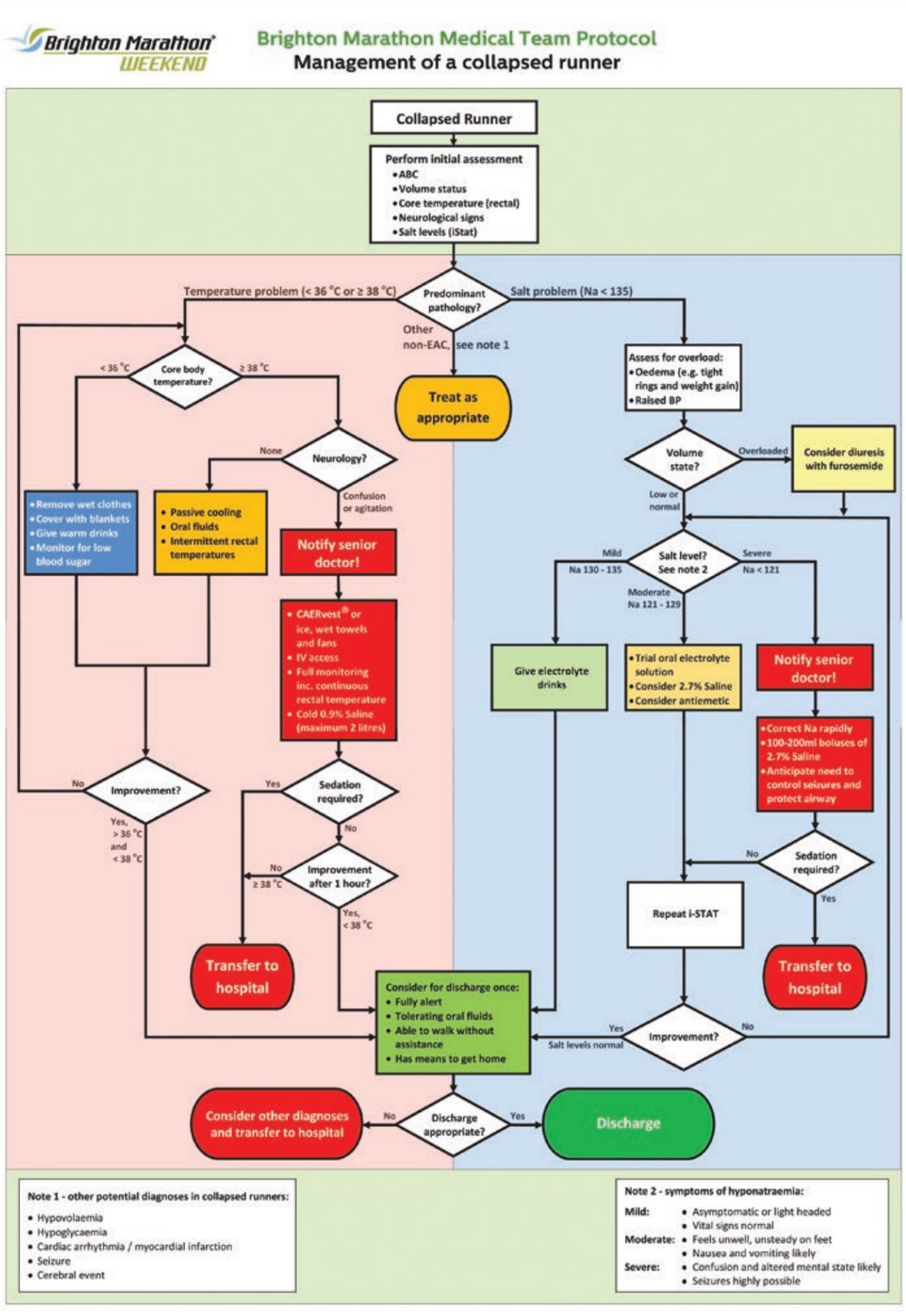
There is a large fleet of ambulances including an Advanced Mobile Medical Unit carrying a doctor with the capability of performing a roadside rapid sequence induction if required. At the Finish Line there are Forward Incident Teams and spotters looking for collapsed runners. A collapsed runner will then be either transported to a first aid room or taken to hospital directly if required.

In 2016 the concept of an Advanced Cardiac Arrest Team (ACAT) was introduced, led by a highly experienced pre-hospital consultant. The ACAT have a dedicated vehicle with a specialised team and equipment, including carbon dioxide monitoring and a LUCAS (automatic chest compression device). If, after 20 minutes of cardiopulmonary resuscitation (CPR) there is no Return of Spontaneous Circulation (ROSC), out of hospital ECMO is started by a team from Barts Health NHS Trust who are embedded within the ACAT. Dr Rachael Grimaldi, Associate Medical Director of the marathon, led the integration of the ECMO team into the ACAT, underpinned by a series of roadside to critical care simulations (*Figure 1*).

THE BRIGHTON MARATHON HANDBOOK

In an effort to ensure consistency of care an event handbook has been developed which is updated annually. The handbook provides essential information for volunteers including a summary of individual roles and responsibilities. An integral component of the handbook is prompt cards and treatment algorithms for medical emergencies including Exercise Associated Collapse, Anaphylaxis and Cardiac Arrest (*Figure 3 next page*).

There is specific reference to the assessment and management of Exertional Heatstroke (EHS), with reference to the Faculty of Sport and Exercise Medicine (FSEM) EHS guidelines which were co-authored by members of the Brighton Marathon medical team. These guidelines have been used to support the International Olympic



Opposite Page:
Figure 3
Management of a collapsed runner

Committee (IOC) decision making processes with particular focus on managing the high temperatures expected during the 2021 summer in Tokyo.

This is especially pertinent to the postponed 2020 Tokyo Olympics due to the concerns regarding the risk of EHS and plans for mitigation of such risk. The handbook provides an evidence based, easy to access resource for the assessment and treatment of commonly seen medical emergencies at endurance events, ensuring safe and effective healthcare provision.

As part of this IOC expert working group, research that can help protect the health of athletes competing in the heat in Tokyo is ongoing (with a research grant of $50,000.00 awarded by the IOC entitled “Protecting athletes’ health through the prevention of heat illness during the 2020 Tokyo summer Olympics”). The Brighton marathon was used as one of the test events prior to the Tokyo Games (albeit the 2020 edition was cancelled due to Covid-19).

- *See the article by Borja Muniz and Konstantinos Angeloudis for further details on the research being done in the build-up to the Tokyo Olympics in this special edition.*

RESEARCH AND EDUCATION

The annual Brighton Marathon Medical Symposium is held the evening before the race and includes expert speakers from across endurance science and medicine. The symposium also offers an opportunity for the research teams to present their work. The Brighton Marathon Research Group is formed of a diverse group of researchers, clinicians, Defence Medical Services doctors and healthcare providers, and led by Dr Rachael Grimaldi.

The group undertakes a wide variety of research topics related to endurance events and the application of evidence from such events to a wider population, including UK service personnel.

A number of research projects were planned for the 2020 Brighton Marathon, but have been postponed until the next live event due to the pandemic.

The Biomarkers After Sporting Incapacity Study (BASIS) was a prospective case-controlled study carried out at the 2019 event, which attempted to answer whether a group of novel biomarkers could be used for the prediction of severity of Exertional Heat Injury (EHI) and subsequent risk of multiorgan dysfunction.

One hundred healthy participants were recruited for blood testing and measures of cardiovascular function before the run and on the finish line.

A further eight cases of heat-related collapse had similar measurements in the medical tent and both groups went on to provide later blood tests.

On the event day, the researchers were able to demonstrate the role of assessment of cardiac function using echocardiography to guide treatment strategies for heat-related collapse and assess for other pathologies, including myocardial infarction. Healthy runners were found to have an increase in a novel echocardiographic index, which is thought to help minimise the impact of dehydration and heat-related changes during endurance events. This novel work was published in the JRSM Cardiovascular Disease.[1]

The findings have informed preparations for BASIS2, with plans for extended measurements such as in-race body temperature and tissue glucose monitoring.

The Renal Function and Marathon Running (ReFRun) study recruited 90 runners at the 2019 event and collected data on pre- and post-race renal function, which was added to data sets from the previous nine Brighton Marathon events.

This work found a higher incidence of abnormally raised serum creatinine than previously reported. The clinical significance of this was not clear as a similar pattern of rise was seen in both collapsed and non-collapsed runners. Resolution was seen within 24 hours. The rate of abnormal sodium concentrations was infrequent and is a potential reflection of updated advice with regards to drinking fluids to quench thirst. This work was published in the European Journal of Emergency Medicine.[2]

The Gut Permeability study aimed to assess the role of increased gut permeability during endurance exercise, in the context of evidence suggesting passage of gut pathogens into the circulation and brain as a cause of morbidity in EHI. The study recruited healthy race finishers and collapsed runners, and measured Intestinal- Fatty Acid Binding Protein (I-FABP) and Lipopolysaccharide (LPS) as markers of intestinal permeability. The results and subsequent write up of this study are currently under peer review.

Other areas of interest and publication include the impact and mechanism of troponin release during endurance exercise,[3,4] and the use of alternative out of hospital cooling techniques.[5]

- **Jonathan Shurlock**
  Somerset NHS Foundation Trust
- **Rachael Grimaldi**
  Brighton and Sussex University Hospitals NHS Trust
- **Rob Galloway**
  Brighton and Sussex University Hospitals NHS Trust

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Paralympic Medicine Research in the University of Brighton

ARTICLE BY **DR NICK WEBBORN**

> **“Did you think you would make plans and life would follow you obediently?”**
>
> *Ludwig Guttmann, 1948*

Above: Kenenisa Bekele completing a week of treatment in Eastbourne (15th July 2015) that served as a career saving intervention by the Sub2 marathon project. Having not been able to run for several months Bekele then only missed the word record in the Berlin Marathon by 2 seconds

The University of Brighton has been integrally involved with Paralympic Sports Medicine research since 2002 and provides the ethical approval for all the illness and injury surveillance research at winter and Summer Paralympic games. It also has a Clinical Professor of Sport and Exercise Medicine in a UK system that has few academic positions.

So how did this come about you may well ask? Life has many surprises and none more shocking for me than, at the age of 24 working as an RAF doctor, to find myself with an incomplete C7 tetraplegia from rugby. The time spent on the receiving end of rehabilitation included nine months at the Spinal Injuries Unit at Stoke Mandeville Hospital and four months at then RAF, later joint services rehabilitation unit, at Headley Court. Unbeknownst to me at the time, they were the perfect grounding for a future career in sports medicine – understanding the rehabilitation process, mental and physical, from the patient perspective.

A few years in primary care preceded my one year full-time diploma in sports medicine in 1992-3 at the Royal London Hospital (now QMUL) before being offered the Lecturer post at the academic department of Sports and Exercise Medicine by the late, and great, John King. My primary role was running the Masters course, but in assisting the students in their projects it gave me a great grounding into the research process.

Also in 1992 I started working with the British Paralympic Association as a medical officer but looking to the literature for guidance I was dismayed at the paucity of information available. In fact, up until 1992 there were just a total of nine articles available in a Pub Med search on this topic. I thought of myself as a clinician with an enquiring mind rather than an academic in those early days, and probably still do if I’m honest.

As a consequence I started writing articles and opinion pieces on the topic and drew the attention of the IPC medical committee and in 2001 was invited to join it. In those days of pre-SEM specialty and pre-lottery funding we were all portfolio doctors trying to earn a living in sports medicine. My primary care role had been in Eastbourne, was also the home to the then Chelsea College of Physical Education, a part of the University of Brighton that offered, amongst others, degrees in sports science and physical education.

Along with a physiotherapy colleague we started a privately run clinic within the sports science department. My publishing record came to the attention of the head of school who offered me a 0.2 contract as Principal Research Fellow to enhance their REF submission and for once it was nice to get paid for all the time spent on academic activity that you normally do in your spare time!

RESEARCH PROJECTS

With my colleagues at the University I was then able to initiate and conduct research projects with access to support and an ethics committee. Now a member of the IPC medical committee I took the opportunity to run the first ever injury survey at a Winter Paralympic Games in Salt Lake in 2002.

Writing an Access database on the plane over to the US, I teamed up with the head of the Polyclinic to capture data on all injuries we could identify. This snapshot of injuries identified five lower limb fractures in the sport of Ice Sledge Hockey and highlighted the lack of mandated leg protection might be implicated. Working with the International Federation we were able to change the sport rules for leg protection and sledge height and since that time there has only been one documented lower limb fracture during Winter Paralympic Games in this sport. The IPC, convinced of the merits of this by my previous work, allowed development of the research programme and my main focus was in athlete health, with particular emphasis on prevention of illness and injury. However Paralympic sports medicine prevention was still at the first stage of the van Mechelen model - assessing the extent of the issue through incidence and severity measurement. We progressed to an international group of researchers focused on injury and illness surveillance, with the University of Brighton providing the ethical approval for all of these studies at the Paralympic games. Numerous peer-reviewed studies came as a result but dissemination of the information was key with the translation into athlete and physician education materials and workshops. I have always believed that any research must be purposeful and in the athlete/patient interest.

Above: Dame Sarah Storey proudly displaying the first gold medal won by ParalympicsGB at London 2012 in the Medical Centre surrounded by members of the medical team holding the newspaper front pages

Left: Nick Webborn talking to the Duke of Sussex about the medical support for the UK Invictus Team at the Invictus Trials at Bath University in 2017

ADDITIONAL OPPORTUNITIES

Additional opportunities to link with sports science colleagues at the University allowed development of further research into the still quite bare cupboard of Paralympic medicine and science. I had based the heat mitigation strategy for the Atlanta Paralympics on theoretical knowledge in Olympians and a study on total body water and water turnover that I undertook for Masters project. However with the Athens Games coming in 2004 I was able to utilise the expertise and heat chamber in the sports science laboratory to examine the benefits of cooling and pre-cooling methods for tetraplegic athletes prior to the Athens Games in 2004 working with Prof Vicky Tolfrey of the Peter Harrison Centre for Disability Sport at Loughborough University.

ACADEMIC ENVIRONMENT

What became clear to me was that there were so many benefits to working with colleagues in an academic environment.

It enabled your own personal development but also gave the ability to find collaboration to help answer clinical questions that nagged at you for years.

For example, outside of the Paralympic research sphere I supervised a PhD student in the biomechanical changes that occur in the Achilles over the course of a standard rehabilitation protocol using shear wave elastography, described a novel injury of a tear to the Fascia Cruris at the attachment to the Achilles and explored the issue of Direct-to-consumer genetic testing for predicting sports performance and talent identification with my colleague Prof Yannis Pitsiladis.

I found that the acquired skills of MSK ultrasound were invaluable to my colleagues in muscle biopsy studies but through their work I learnt too. I have also been delighted to introduce honorary research fellows to the academic support that I had, to enable them in their development.

Dr Dan Fitzpatrick has been working on the topic of head collisions and concussion in Blind Football continuing the Paralympic engagement and Dr Bryce Dyer completing his PhD on a holistic product development approach to para-cycling prosthetic limb design.

SEVEN SECRETS OF HAPPINESS

As I return to my passion of the topic of Paralympic medical research I can reflect that there were over 150 publications in the last year alone on PubMed, from the total of nine altogether when I started in the field. But also that I had no idea where my professional life would lead after the difficult early days post-injury.

For those of you that remember Dr Anthony Clare from his ‘In the psychiatrist’s chair’ series of interviews on Radio 4, he talks about his ‘Seven secrets of happiness’.

The first two are: *To cultivate a passion* and *To be part of something bigger than yourself* and in Sports Medicine, academia and in the Paralympic Movement I have found my happiness.

So I would advise any aspiring sports physician to find what that ‘something’ is for them, be open to opportunity and do not expect the path to be smooth. Anthony Clare’s next three points are: to avoid introspection, accept change and to live in the moment.

For as Sir Ludwig Guttmann said in 1948 “Did you think you would make plans and life would follow you obediently?”

• **Dr Nick Webborn**
University of Brighton

THE TAVISTOCK TRANSGENDER ATHLETE STUDY (TTAS)

Integrating transwomen and differences of sex development (DSD) athletes into elite women's sport

ARTICLE BY **BLAIR HAMILTON** [1-3] , **FERGUS GUPPY** [2] AND **YANNIS P. PITSILADIS** [1,4,5]

1. Collaborating Centre of Sports Medicine, University of Brighton, Eastbourne, UK, **2.** Centre for Stress and Age-related Disease, University of Brighton, Eastbourne, UK, **3.** The Gender Identity Clinic Tavistock and Portman NHS Foundation Trust, London, UK, **4.** Department of Movement, Human and Health Sciences, University of Rome "Foro Italico," Rome, Italy, **5.** International Federation of Sports Medicine (FIMS), Lausanne, Switzerland

Above: Hamilton makes a save with her left boot for Montpelier Villa during a 3-1 loss to Chichester City

Right: Hamilton performing fitness testing during a locally funded football project run by VYD C.I.C

The question of the eligibility of athletes to participate in the elite female category of sports has been thrust into the public spotlight for both transwomen and differences of sex development (DSD) female athletes. Here we attempt to clarify some of the difficult issues and offer a roadmap to an evidence-based solution.

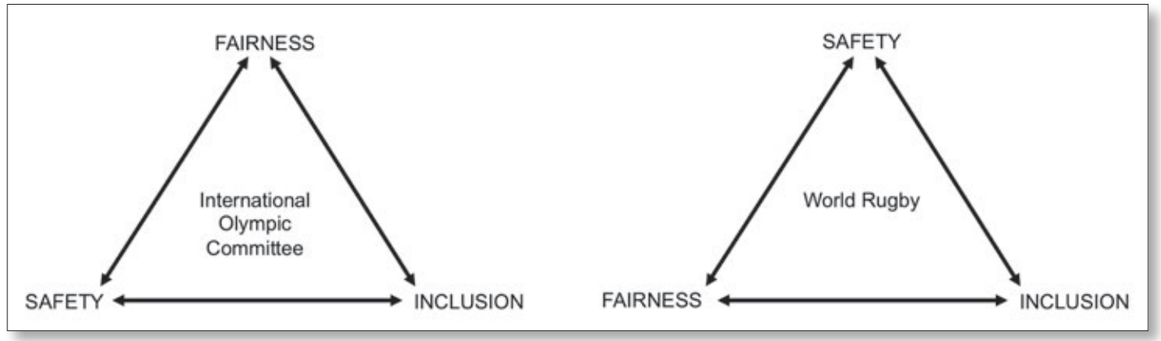
TRANSWOMEN ATHLETES

World Rugby recently proposed a blanket ban on the participation of transgender athletes in the female elite category based on player welfare (available at *https://playerwelfare.worldrugby.org/?documentid=231*) and a number of high profile Olympic athletes have applauded World Rugby's decision, while some leading scientists have criticised the "hypothetical" nature of the biological male vs biological female evidence cited for the guidelines, while Unions such as England, Canada and USA Rugby have refused to implement the new guidelines due to a "lack of evidence" and its "discriminatory nature".

To support exclusion, there has to be clear scientific evidence that there is a real safety threat, and World Rugby's policy focuses primarily on the physiological differences between male and female elite athletes to create hypothetical modelling to showcase the safety risk to cisgender female rugby players from transwomen rugby players, which represents an overly simplified extrapolation. World Rugby also draws on numerous longitudinal research studies that have tracked the physiological changes in untrained transwomen, such as reductions in muscle mass and strength, while the real physiological changes in trained transgender athletes remains unknown. Therefore, the paucity of direct evidence to support exclusion, questions the fairness of the policy of World Rugby to exclude transwomen athletes. World Rugby has elected to adopt a cautious approach and while the safety concern for cisgender female players may indeed turn out to be true, these safety concerns need to be scientifically justified. At the same time, the decision by World Rugby to exclude transgender athletes is also discriminatory to transwomen athletes and in conflict with the fundamental aspects of the Olympic Charter. (*https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/General/EN-Olympic-Charter.pdf*)

SAFE INTEGRATION

As nicely described by Professor Ross Tucker (one of the experts utilised by World Rugby who explains the process used by World Rugby to create their policy (*https://vimeo.com/475933330*), the three main arguments needing to be considered when formulating the guidelines and/or rules for the fair and safe integration of transgender athletes in world sport are fairness, safety, and inclusion but also essentially, their respective weightings



Above: Figure 1 - Implied weightings for the IOC (left) and World Rugby (right) of the three primary criteria for formulating the guidelines and/or rules for the fair and safe integration of transgender athletes

of importance – akin to a triangular argument depicted in Figure 1. One gets a sense of the IOC's weighting of these arguments by examining the 2015 IOC Consensus on Sex Reassignment and Hyperandrogenism. In this document it states *"It is necessary to ensure insofar as possible that trans athletes are not excluded from the opportunity to participate in sporting competition"* and "*The overriding sporting objective is and remains the guarantee of fair competition".*

The IOC Consensus document as written conveys the message that the IOC prioritises athletic fairness over safety (as does World Rowing), whereas World Rugby professes to put safety at the top of their triangle of priorities (*see Figure 1*), therefore reaching the conclusion to exclude transwomen athletes from elite level competition. While it makes intuitive sense that the safety of athletes, especially in a contact sport like rugby has to be the overriding concern and priority, there remains very little direct evidence to support the safety argument to exclude transgender athletes.

This scientific reality also prevails in terms of the view that transwomen have a sporting advantage; a view that has now been strongly re-enforced by the recent World Rugby policy. However, performance data in transgender athletes is urgently needed to inform policy, especially transwomen's but not neglecting transmen because of the reliance on non-sports performance data. The current consensus in the literature [1, 2] is that transwomen, during their gender-affirming treatment for gender dysphoria and subsequent cross-sex hormone therapy, have reductions in performance-related physiological parameters such as haemoglobin concentration, muscle mass, cross-sectional area and strength, coupled with an increase in fat mass. A recent study by Wiik *et al.*[2], which incidentally is the first study to compare outcome measures in transwomen after 12 months of treatment versus control, found that in transwomen, thigh muscle volume decreased by -5% (muscle volume) and quadriceps cross-sectional area (CSA) by -4%, while strength was generally maintained over the assessment period. The limitation, however, of such evidence and most of the literature pertaining to transwomen is the reliance on physiological measures obtained in untrained transgender individuals, and without any focus on measures of sports performance.

The only study to investigate transwomen's sporting performance was an observational study by Harper [3] who in a pioneering way investigated the self-reported running times of transwomen masters runners before and after their respective transitions. Harper found, using a method called "age grading" which is a method of comparing the performance of athletes of all ages and both sexes, found similar age-graded scores for both genders in the eight runners assessed. As this is the only study, conducted in non-elite athletes as well as relying on self-report, there is an urgent need for replication as well as studies conducted in well-trained transgender athletes involved in numerous sports.

DSD ATHLETES

There is no more prominent public case in DSD athletes than the case of the South African runner Caster Semenya, who recently lost her appeal to the Swiss Federal Tribunal against the restrictions of blood testosterone concentrations in female athletes. The argument put forward by World Athletics is that DSD athletes competing in female sports in events between 400m and 1500m possess unfair advantages created by the effect of high levels of testosterone on physiological function[4]. The issue with such a policy is that there is no direct scientific evidence that women athletes with DSD have performance advantages in these specific sporting events. There is, however, observational data that shows a clear difference in performance in DSD athletes depending on whether testosterone concentration was suppressed or not, with an average performance reduction of approximately 5.7% in three athletes who had T concentration suppressed from 21-25 to 2 nmol/l over 2 years[5]. A low number granted (n=3) but an indicator of the performance advantage held by DSD athletes.

Although conditions such as DSD are rare, hyperandrogenic 46 XY karyotype females in the 2011 World Championships were 140 times more prevalent than in the general population[6], another indicator, albeit indirect, of an athletic advantage. However, it is important to note that testosterone concentrations in DSD athletes will not have the same universal effect on each athlete, due to there being athletes with androgen insensitivity which can be either complete or partial. This complexity needs to be considered if testosterone concentrations, either as a single parameter which is already being used [4], or more likely as one of several parameters, will evolve into a viable solution.

Above: Hamilton, dejected and disappointed on the floor after conceding a goal

CHALLENGES

World Rugby Transwomen policy relies heavily on a study by Hilton and Lundberg [7] which at the time of consideration by World Rugby was in the form of a preprint (a challenge in itself as it has not been peer-reviewed, an integral part of the scientific process). Hilton and Lundberg argue *"that sporting advantage conferred by skeletal size and bone density would be retained despite testosterone reductions[7]"* in transwomen. However, injuries in sport are the result of an interplay of complex and dynamic systems [8] and injury prevention is often related to better skill and technique training [9] rather than the size differential of players, which seems to be the main argument adopted by World Rugby to support their exclusion policy. This argument stems from Hilton and Lundberg's approach of comparing the achievements and biology of cis male athletes and cis female athletes and extrapolating this sporting advantage to transwomen athletes.

By doing so, Hilton and Lundberg can be said to imply that transwomen athletes retain the primary biology and sporting advantages of cis males, which represents an overly simplified view. One should not forget that testosterone, the single hormonal parameter suggested for the inclusion of athletes in the female category is not just a male-exclusive hormone, females need and produce testosterone for their health and developmental benefit [10]. Therefore, there is an urgent need to document the changes in sporting performance measures in trained transgender athletes. The changes in physiology during transition (i.e., both in male to female and female to male transitions) are well documented over 12-24 months. It is time for the scientific community to shift the focus of the science to trained transwomen and transmen and to elucidate the changes in physiology and sporting performance of well-trained transgender individuals for at least 48 months to generate the data needed to create a fit for purpose policy to guide international sports federations.

In addition to the above, the United Nations Human Rights Council's (UNHRC) recent recommendations to remove the eligibility rules that amounts to allowing athletes to self-identify into women's elite sporting category [11] creates a dilemma for the integrity of sporting competition at the elite level. The evidence of testosterones effects in male and female sport is clear. However, the scientific evidence is scarce on the effects of endogenous testosterone concentrations on individual sporting performance of athletes with DSDs. We have recently outlined our grave concerns in a letter accepted to the Editor of Sports Medicine [12] that also outlines an urgent need for continued research to developing new policies that include fair DSD athlete competition. Until such studies are concluded, we must not abandon all eligibility rules for the female classification within sports.

THE TAVISTOCK TRANSGENDER ATHLETE STUDY

How does science solve the question of integrating transwomen and DSD athletes into the elite female category? The use of science alone is destined to fail as sports performance is so multifactorial (not to mention the political dimension) that science will never be able to explain or indeed eliminate all differences between one athlete and another. Scientific approaches also continuously evolve, where many of the techniques we use today in science are destined to be obsolete in less than 10 years from now. It is vitally important, therefore, that science continues to provide the evidence to support and update sports policies, only as the scientific evidence develops and not via common sense intuition, however prophetic common sense may prove in the future.

With this objective in mind, the Collaborating Centre of Sports Medicine at the University of Brighton have proposed the largest study of its kind, *The Tavistock Transgender Athlete Study (TTAS)* [13], which is a unique collaboration with the Tavistock and Portman NHS trust. The TTAS will track 20 athletic transwomen and 20 athletic transmen, throughout their gender-affirming treatment from baseline to 24 months and compare both to a female athletic cohort of 20 university female athletes. Importantly and taking heed of previous gaps in the literature, sports performance indicators such as maximal oxygen uptake, lung function tests, and strength and power measurements of transgender athletes. The TTAS has been designed specifically to help inform policy, with scientific evidence at its core.

The TTAS also seeks to answer the new science of *"muscle memory[14]"* in transgender athletes, which proposes that previous exposure to testosterone in transwomen, results in a peak pegging of myonuclei number in muscle, resulting in a quicker return to a hypertrophic muscle state after a period of muscle detraining. If a significant "muscle memory" remains in transwomen, as it appears to be in mice [15], this potentially could be an irremovable advantage depending on the length of this advantage which currently remains unknown [16], that sporting policymakers would have to consider.

The Covid-19 pandemic has already delayed the initiation of data collection by around 10 months, with preliminary data collection now planned for January 2021 or soon thereafter depending on Covid-19. To date we have recruited 11 transwomen and 6 transmen, all very excited and eager to participate. *See TTAS advert above for further details.*

Although the TTAS is based solely on transgender athletes, it may help to inform policies on DSD athletes by showing the effects of testosterone suppression or administration have on sporting performance measures.

It is essential, however, that the emotion and heat of the subject be replaced with a focus on scientific enquiry and evidence.

Blair Hamilton is a transwoman athlete originally from the west coast of Scotland, who transitioned in early 2017 and 2018 became the first transwoman to play football in the Scottish Women's Football pyramid playing at the Championship level with Stonehaven Ladies FC, Grampian Ladies FC, as well as the top British University and College Sport level in Scotland with Aberdeen University.

Playing as a goalkeeper, Blair is currently playing her football with Montpelier Villa's Women's and University of Brighton Women' teams in Brighton.

Graduating from the University of Aberdeen in June 2019 with an honour's degree in exercise and health science, she discovered her passion for research after undertaking her honours project which involved tracking male and female performance in football with Statsports™ GPS software, including her own performance data while playing for the University of Aberdeen and comparing it with cisgender female and male players, thought to be first direct data on trans sporting performance in football.

Blair now resides in Hove with her undertaking a PhD the University of Brighton, teaming up with Professor Yannis Pitsiladis and Dr Fergus Guppy to bring the TTAS to life.

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TECHNOLOGICAL DOPING: How we opened Pandora's Box...

ARTICLE BY **BORJA MUÑIZ-PARDOS**[1], **KONSTANTINOS ANGELOUDIS**[2], **FERGUS GUPPY**[3], **SHAUN SUTEHALL**[4], **ANDREW BOSH**[4] AND **YANNIS PITSILADIS**[5]

1. GENUD research group, Faculty of Sport and Health Sciences, Department of Physiatry and Nursing, University of Zaragoza, Zaragoza, Spain, **2.** Collaborating Centre of Sports Medicine, University of Brighton, Eastbourne, UK, **3.** Centre for Stress and Age-related Disease, School of Pharmacy and Biomolecular Sciences (PaBS), University of Brighton, Brighton, UK, **4.** Division of Exercise Science and Sports Medicine, University of Cape Town, Cape Town, South Africa, **5.** International Federation of Sports Medicine (FIMS), Lausanne, Switzerland

We consider "Technological doping" as the performance advantage provided by technology that determines the outcome of the competition. In terms of the recent focus on carbon fiber plate (CFP) running shoes [1], the irony is that we, as the Sub2 marathon project [2], conceived of the idea to focus on developing innovations that would allow athletes to utilize and fulfill their full biological potential without the need to resort to doping. This unique but essentially an anti-doping project was launched in Newcastle in December 2014 (at the International Sport and Exercise Nutrition Conference ISENC14 annual event) with the "headline" attracting goal to break the 2hr barrier in the marathon[3]. In fact, the project had at its core a holistic anti-doping focus – developed from "out of the box" thinking [4]. Briefly, a solution that encompasses a holistic anti-doping approach comprising of at least three primary anti-doping pillars (*see Figure 1*) motivated by the need to prevent doping, protect the clean athlete, and promote performance without doping (3Ps).

A major research priority in the Eastbourne laboratory is the application of "omics" (i.e., genomics, transcriptomics, and metabolomics) for the detection of drugs in sport with particular reference to recombinant human erythropoietin (rHuEpo), blood doping and testosterone. Most of our recent research is funded by the World Anti-Doping Agency (WADA) and by the International Olympic Committee (IOC), with the primary focus on the evolution of the anti-doping process that underpins the first two 3Ps - prevent doping and protect the clean athlete (*see Giscard Lima's article in this series*).

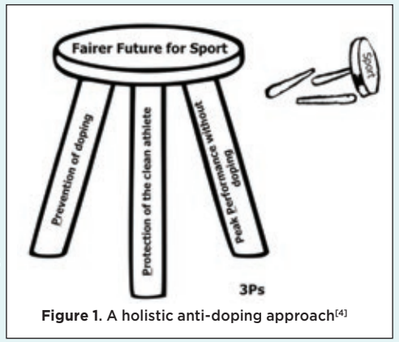

Figure 1. A holistic anti-doping approach[4]

PEAK PERFORMANCE DEVELOPMENT

Our years of experience within elite sport has taught us that this evolution or modernisation of the anti-doping process had to embrace peak performance development of all forms that do not violate anti-doping rules and/or the rules of the sport; the third of the 3Ps - promote performance without doping.

As we have previously argued [4], modern day sport is big business, no longer an amateur pastime for the privileged few but a vocation for thousands of athletes and their extensive entourage of physiologists, nutritionists, biomechanists, psychologists, and the like.

The original Sub2 marathon project [2] emerged in response to this professionalisation of sport but also threats to sports integrity [5]. The Sub2 project was the first dedicated international research initiative made up of specialist multidisciplinary scientists from academia, elite athletes, and strategic industry partners with the aim to promote high-performance marathon running without doping. In terms of anti-doping, all athletes participating in the Sub2 project needed to undergo regular doping controls (blood and urine) in accordance with WADA's anti-doping regulations.

Additionally, the Sub2 project pioneered a new WADA+ programme [2] that involved adding extra information/education, extra testing, and extra storage of samples – does this not sound like what is now being done by the Athletics Integrity Unit (AIU) [6]?

The AIU represents one of the most successful anti-doping systems in recent memory run by David Howman (the Former Director General of WADA for 13 years until 2016 and now chair of the AIU).

In short, the unique experiences gained from this innovative anti-doping project were being used to strengthen anti-doping intelligence and ongoing scientific research. While there were no guarantees the Sub2 marathon project would succeed in delivering a sub 2-h marathon within 5 years, a number of legacy outcomes beyond the breaking of the 2-h barrier were envisaged including the promotion of clean high performance marathon running, development of next-generation anti-doping tests, personalised medicine/rehabilitation, individualised training, performance nutrition, customized racing footwear designs, and real-time performance management systems with broader telemedicine implications (i.e., ironically, the summary of this special edition in BASEM Today). This was the ambitious and altruistic original idea and not the opening of "*pandora's box*" as it unfortunately transpired.

"MARKETING" PROJECTS

The success of this innovative anti-doping project, attracted "marketing" projects such as Nike's Breaking2 project [7] and INEOS 1:59 Challenge [8], although these projects did not have an anti-doping focus [9] and were organized by a breakaway group part of the original Sub2 project.

The first attempt to run a sub 2-h marathon took place on May 6, 2017, by a Kenyan distance runner named Eliud Kipchoge, who ran the marathon distance (42.195 km) in 2:00:25 at the Monza race track, Italy. This athlete benefited from "unfair"' advantages (e.g., car drafting and rotating pacemakers [10]), no anti-doping control, and controversial CFP running shoes passed as legal by the IAAF technical committee only days before the Breaking2 attempt despite the shoe allegedly making runners up to 4% more efficient[11].

The success of the third pillar, peak performance without doping, requires sport itself to modernise by continuing to


NIKE win Gold, Silver and Bronze

welcome technological advances. Examples of such advances have been witnessed in tracks when they upgraded from cinder to synthetic rubber, in pole vault when poles evolved from bamboo to fiberglass, or in shoes when these began for cushioning to incorporate air bladders, gels, and now a CFP in the midsole.

Additional technological advancements were triggered by the introduction of a rule (144.4(d) by the IAAF (now World Athletics) allowing athletes to wear different devices during an event to monitor physiological/biomechanical/performance-related parameters (e.g., heart rate, speed distance or stride sensors). Such technological innovations would be allowed when strictly in accordance with the rules and principles of fair competition, such as the principle of universality of sport (i.e., being available to all athletes) and implemented in a way that the technology does not determine or distort the outcome of the competition (e.g., record tables).

SPORTS INTEGRITY

Technological advances to improve athletic performance are historically considered ethical and part and parcel of progress, and as such, acclaimed and considered to be part of the lore of Athleticism as long as equity between competitors and sports integrity is guaranteed. In stark contrast to this idea, the launch of CFP shoes by Nike in 2016 has resulted in all men's and women's world records in running (i.e., from 5 km to marathon) broken by athletes wearing shoes containing CFPs (*Table 1*). This phenomenon is raising concerns that the introduction of this technology leads to a distinct non-physiological advantage [12]. The first event in which the dominance of CFP was noticeable was during the Olympic marathon in Rio de Janeiro (2016), where all medals in both the men and women races were won by athletes wearing CFP shoes.

Although the use of CFP shoes has been restricted to Nike-sponsored athletes during the last four years, 2020 has seen how a number of further companies (e.g., Asics, Brooks, Adidas and Saucony) have reacted by designing their own CFP shoe aiming to provide their athletes with a competitive advantage. Although there is now a total of nine shoe companies offering their own CFP road shoe, there are still non-sponsored athletes who will not have access to CFP shoes. Additionally, there is the issue that Nike is the only company, for the moment, that has created CFP spikes and even more records are expected in track events in Nike-sponsored athletes.

EXPANDING TECHNOLOGY

Since summer 2020 CFP technology has been expanded also to track events with the new Nike CFP spikes. Despite no scientific data demonstrating its impact upon performance, this technology is already having a major impact with 5 world records in only 3 months (*Table 1*). An illustration of the immediate spread and popularity of CFP spikes was noted during the 2020 Diamond League in Monaco (14th of August 2020). Of the 65 athletes competing in races between 800 and 5,000 m, 50 athletes wore Nike spikes, and 27 of these athletes wore the new CFP spikes. During this event, the 5,000 m World Record was broken by an athlete wearing a CFP shoe; a record that had stood for 16 years.

The sudden improvements in performance times witnessed since the emergence of CFP shoes in 2016 are technologically driven rather than physiological. The magnitude of race performance improvements by athletes running in CFP shoes are analogous to those expected from various blood doping substances and methods included on the prohibited list of the World Anti-Doping Agency (WADA), such as erythropoietin, which have been shown to improve performance by 4-6% [13,14].

On 31st January 2020, World Athletics reacted to this controversy in shoe technology by announcing new rules stating that sole thickness of a marathon shoe must not exceed 40 mm (30 mm for spiked shoes) and must be on sale for at least four months before they can be used in competition 15. Soon after, Nike launched the Alphafly shoe with a 39.5 mm sole, a CFP insert, and the addition of air pods in the metatarsal region.

The close proximity of the Alphafly launch to the new

TABLE 1. MALE AND FEMALE WORLD RECORDS IN LONG DISTANCE RUNNING (DATED 16/11/20)

MALE

Race	Performance	Athlete	Date	Shoe used
5 km	12:51	Joshua Cheptegei	16/02/2020	Nike ZoomX Vaporfly Next%
5.000m (track)	12:35.36	Joshua Cheptegei	14/08/2020	Nike ZoomX Dragonfly
10 km	26:24	Rhonex Kipruto	12/01/2020	Adidas Adizero Takumi Sen 5
10.000m (track)	26:11.00	Joshua Cheptegei	07/10/2020	Nike ZoomX Dragonfly
15 km	41:05	Joshua Cheptegei	18/11/2018	Nike ZoomX Vaporfly Next%
½ marathon	58:01	Geoffrey Kamworor	15/09/19	Nike ZoomX Vaporfly Next%
1 hour	21,330m	Mohamd Farah	04/09/2020	Nike ZoomX Dragonfly
Marathon	2:01:39	Eliud Kipchoge	16/09/2018	Nike Zoom Vaporfly 4%

FEMALE

5 km (W)	14:44	Sifan Hassan	17/02/2019	Nike ZoomX Vaporfly Next%
5.000m (track)	14:06.62	Letesenbet Gidey	07/10/2020	Nike ZoomX Dragonfly
10 km (Mx)	29:43	Joyciline Jepkosgei	09/09/2017	Adidas Adizero Takumi Sen 5
15 km (Mx)	44:21	Letesenbet Gidey	17/11/2019	Nike ZoomX Vaporfly Next%
½ maratón (Mx)	01:04:31	Ababel Yeshaneh	21/02/2020	Nike ZoomX Vaporfly Next%
½ maratón (W)	01:05:16	Peres Jepchirchir	17/10/2020	Adidas Adizero Adios Pro
1 hour (W)	18,930m	Sifan Hassan	04/09/2020	Nike ZoomX Dragonfly
Marathon (Mx)	2:14:04	Brigid Kosgei	13/10/2019	Nike ZoomX Vaporfly Next%
Marathon (W)	2:17:01	Mary Keitany	23/04/2017	Adidas Adizero Takumi Sen 5

W= women-only race; Mx= men and women mixed race

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regulation announcement raised concerns that the rules had been drafted to "legitimise" Nike's CFP shoe series in response to accusations of "technological doping"[16], doing little to protect the principle of fairness in sporting competition. These new rules have resulted in a footwear arms race to develop patented CFP inserts by numerous shoe companies. This is contrary to another important principle of fairness in sport – the universality of sport, where technological developments used by athletes need to be reasonably available to all competitors. The cost of these shoes (most of them above £200) would limit its availability only to a minority of athletes, being inaccessible for the largest sections of society especially from underdeveloped countries, ironically alienating many East Africans, who have dominated long-distance running worldwide for more than 50 years.

A POTENTIAL SOLUTION TOWARDS EQUITY AND FAIRNESS IN SPORT

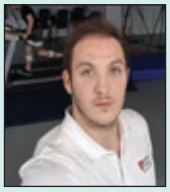
The one-year postponement of the 2020 Tokyo Olympic Games due to the COVID-19 pandemic provides the opportunity for World Athletics to commission an independent review focusing on technological fairness to systematically evaluate the impact of technology on the essence and integrity of sporting competition.

The controversy today surrounding the "legality" and "ethics" of CFP shoes is not unprecedented. In 2009, the International Swimming Federation (FINA) was obliged to modify the rules and ban full-body swimsuits in response to numerous sudden world records broken by swimmers wearing this technology. Similarly, the IAAF (now World Athletics) faced their own technological issue with shoe designs in the 1960s. In the latter case, both the 200 and 400 m world records were broken within the space of two weeks in 1968, with both athletes wearing the newly developed "brush" shoe[17] (i.e., a shoe containing 68 small pins). This led to the banning of this technological advancement by the athletics governing body and all records broken with these shoes erased from the records.

The recent decision by World Athletics to permit the use of CFP shoes throughout the sport of athletics (including track) is contrary to previous decisions regarding the use of technological ergogenic aids; a decision that must be urgently and carefully reconsidered.

A potential solution to solve this issue would include the reduction of the maximal stack height of a shoe to 20 mm, so that the ergogenic effect and performance benefit provided by a shoe would be limited. Companies would be able to innovate within this space, but shoe technology would be stopped from determining current performance improvements.

Dr Borja Muniz-Pardos is a senior research fellow and lecturer at the FIMS (International Federation of Sports Medicine, www.fims.org) Collaborating Centre of Sports Medicine (FIMS CCSM) at the University of Zaragoza (Spain) and conducted in partnership with the Sub2 marathon project (*www.sub2hrs.com*).
Borja completed his doctorate studies in 2019 with the highest-level award as part of the GENUD (Growth, Exercise, Nutrition and Development) research group at the University of Zaragoza. His research to date has focused on the holistic underpinning of human performance with particular focus on sports integrity and the investigation of ergogenic aids such as next generation sports drinks, brain stimulation, altitude training, doping with erythropoietin, blood-flow restriction training and the application of wearable technology in health and elite sport. His current research priority is to elucidate the physiological and metabolic responses of blood-flow restriction training (the KAATSU paradigm) and its effectiveness as a training and rehabilitation (and prehabilitation) modality in both health and disease. Borja's most recent research is being conducted in partnership with the World Olympians Association (WOA, *https://olympians.org*) and funded by kaatsu-global (*www.kaatsu.com*).



Konstantinos Angeloudis, BESS (Hons) MSc, currently is a PhD candidate (Doctoral researcher) in applied biomechanics, muscle and running mechanics research in the Collaborating Centre of Sports Medicine at the University of Brighton, Eastbourne, UK.
His research focuses on the development and integration of wearable sensors and technologies with a particular focus on foot biomechanics and running mechanics. He conducted research into applied biomechanics as a research assistant, focusing on biomechanical data analysis, gait analysis research, signal processing and kinetic and kinematic methods applied to the analysis of the motor mechanism of human performance, contributing several abstracts of analytical methods in the field of biomechanics."

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